



2012 International Symposium on Safety Science and Technology The personal protection of emergency rescuers in dangerous chemical accidents

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Abstract

This paper discusses personal protective principles of emergency rescuers which is based on the requirements of fast, accurate and effective emergency rescue in dangerous chemical accidents. Firstly, this paper analyzes the emergency plan and the preparation that we need make for personal protection of rescuers. Then, this paper uses all kinds of exposure limiting concentration of dangerous chemical to classify the initial quarantine, protective area, hot area, warmer area and cold area on the basis of the planning guide on emergency response of polluted air (American industrial hygiene association). Finally, this paper defines area operations, qualifications requirements of rescuers in area, principles of division, protective objects for different areas, so as to determine the personal protection level of emergency rescuers in various areas, which can provide reference for the personal protection of emergency rescuers in dangerous chemical accidents.

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Keywords: dangerous chemicals; accident; emergency rescuers; personal protection

1. Introduction

The emergency rescue in dangerous chemical accidents is different from the general rescue and environmental testing, so rescuers must consider their own protection. Otherwise, it not only can not control the rescue, but it may cause poisoning and even endanger their lives. For example, in December 1999, epoxy ethane leakage happened in a certain place. There were ten rescuers who joined in the rescue and monitored to be poisoned by the epoxy ethane because of wearing protective supplies improperly. Another example, one sewage treatment plant happened poisoning accident, rescue workers died one after another in well and caused even greater casualties because of wearing protective supplies improperly. From the above we can know the personal protection of emergency rescuers in dangerous chemical accidents is not just a simple problem of dress, and it relates to its own security and overall efficiency of the mission, so relevant government departments and public health workers should pay much attention to it[1].

2. Current situation of the personal protection of emergency rescuers in dangerous chemical accidents

Regulations of Public Health Affairs Outbreak in our country formulates that workers who take part in the rescue must take healthy protection measures, and any personal or organization can't violate protection requirements and can not compel others (or institution) without proper protection to enter into the rescue site without authorization. Any rescuers under the situation without protection should not expose to the environment that can be or may be harmful to their health[2].

Because the emergency rescue in dangerous chemical accidents has those characteristics of high risk, high strength and pressing, rescue workers must do fast reaction, and cannot take conventional protection program, and the personal protective equipment is the preferred protective measures to prevent in the emergency response. But any protection is limited, and the use of personal protective equipment only can reduce the risk to the lowest possibility in high-risk environment, so it depends on the adequacy of the risk assessment and preparation prior to the work, the rational division of

risk areas, and proper use and operation ability of users, etc. Even if every link has realized the optimization, but objectively speaking, it still cannot guarantee absolute safety.

3. Emergency plan and response

We make emergency plan for possible accidents according to relevant regulations and requirements. In the compiling process of emergency plan, it should pay attention to the participation and training of all the staff, so that all persons in concern with accidents know the hazard, the emergency response plan and skills. Emergency plan should make full use of social emergency resources, and connect to local government plan, the supervisor units and plans of related departments. The purpose of preparing emergency plan is: when the accident is inevitable, it can make the enterprise be free from or less damage, and prevent accident deterioration, and strive for the shortest possible time to recover the production. The emergency plan of dangerous chemical accident includes: deployment of organization, personnel, and equipment, and feasible scheme of emergency disposal.

3.1. Deployment of organization and personnel

To build strong emergency organization is the key to implement the emergency plan. Sound emergency organization shall include the emergency treatment's leading institutions, professional and voluntary rescue team and other necessary personnel of medical treatment, logistics, and safeguard etc. In terms of the specific company, it should carry out responsibility to every person.

3.2. Allocation of emergency equipment

Emergency equipment shall include the following aspects: (1) alarm system: it mainly has the fire alarm device (fire detector, fire controller, etc), monitoring alarm device of gas and dust explosion (monitoring device of explosive gas, alarm breaker, telemetry alarming device, and monitoring device of explosive dust, etc) and poison gas leakage alarming apparatus, etc. (2) equipment of rescue personnel: it mainly refers to helmet, protective clothing, protective boots, respiration protective appliances, safety belt, rope and other equipment. (3) fire equipment: it mainly refers to the fire extinguisher, flame retardant, special fire engines and simple fire fighting tools, etc. (4) life-saving equipment: it mainly refers to the automatic resuscitator, respirator etc. (5) communication equipment: emergency plan should consider the destruction of the original communication system, and use the emergency communication tool [3].

3.3. Response of emergency rescue in chemical accidents

The organization and implementation of emergency rescue in chemical accidents directly relates to the success or failure of the rescue work. In the complex rescue work, organization is more important. The orderly organization is the basic guarantee to implement emergency rescue. The implementation of emergency rescue in chemical accidents can be done by the following basic steps [4] :

Accurately understanding the initial information such as the nature and scale of accident is the key to start the emergency rescue and is the first step to carry out the rescue work, and plays an important role in the preparation of the personal protection of emergency rescuers in dangerous chemical accident. Report as the first step of emergency rescue must be explicitly stipulated and defined. It should be clear about alarm telephone for 24 hours, and establish procedures of receiving and notifying accidents. List all the notification object and telephone, then timely notify accident information according to the object and the phone list. Report is on duty by the general staff. The notified personnel must know the following conditions: (1) name, unit department and contact phone number; (2) when and where the accident happened, accident unit, the cause of the accident, main poison, character of accident (toxic spilling, explosion, burning), the scope and extent that harm affected; (3) the requirements to the rescue and making the phone records. After report personnel knows basic accident, he or she immediately notices enterprise leadership, and reports the accident situation, and sends rescue teams according to rescue program. He need keep contact with first aid team, and send the subsequent echelon to give reinforcements depending on the accident development status when necessary.

Report to the superior departments which are concerned, and report information content as follows: (1) name and address of enterprise which already has had an accident or leakage; (2) name and phone number of the man who has reported; (3) chemical name of leakage need be known, and whether the chemical is a exceeding hazard substance or not; (4) the leakage time or anticipated duration; (5) the actual or estimated leakage. Whether it can have an external effect on enterprise, and it may cause harm to the society; (6) the medium that leakage has produced ; (7) known or expected acute or chronic health

hazard that accident may cause and the medical advice and protective measures for contact personnel ; (8) emergency rescue measures which should be or has taken; (9) whether it need ask the social relief and related suggestions; (10)others: weather conditions such as wind direction, wind speed. Chemical enterprise is as an example, and the network diagram of information transmission is as shown in Fig. 1 [5].

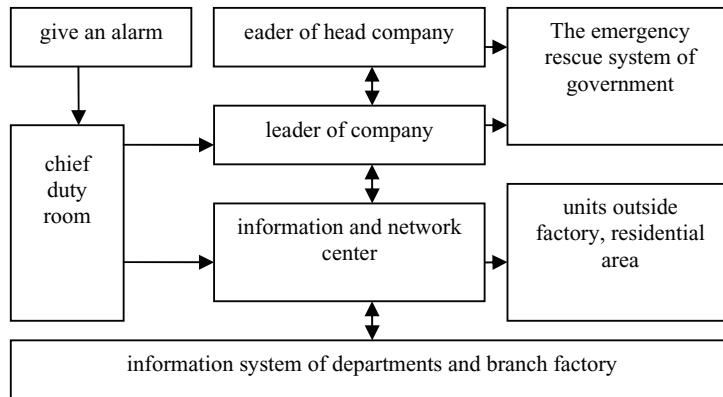


Fig.1 Network diagram of information transmission

4. Regional division

After the accident of emergency rescue in dangerous chemical happened, the primary task is to evacuate the personnel, and determine the safety distance and establish a safe area. From a security point of view to protect personnel, of course, the safe distance is as far as possible. However, in addition to the safety factor should be considered in the rescue, how to dispose accident as soon as possible and prevent the spread and expanding of accident should also be considered. Therefore, it is necessary to set up the quantitative analysis method to determine the safety area. The safety area not only can satisfy the actual requirement in site rescue, but it can guarantee the personal safety of people around and emergency rescuers in site.

At present, developed countries such as Europe and the United States has established a more mature method to determine the safety area in chemical accident. Such as: transportation departments in North America provides the isolation and protective distance of thousands of chemical at the first time for chemical accidents which occurred in the process of transportation, which offers scientific basis for command personnel to rescue and handling personnel in field to do the preliminary decision. American industrial hygiene association has established emergency evacuation and protective distance for more than one hundred kinds of chemical, and increases 7 kinds of new chemical materials each year.

4.1. Initial quarantine and protection area

After chemical leakage, if someone contacts leakage, or sucks the steam, he may endanger his life, so it is necessary to determine the initial zone which provides reference for the emergency personnel before the professional personnel arrive at site of the accident. The initial safety zone includes initial quarantine and protection area. It refers to the area which need to control at n downwind direction and around source after accident of toxic chemical leakage happens in order to protect the public from injuries in the accident. This area can provide the guidance for emergency rescue workers at the first time before emergency rescue personnel with technical data reach the place. The diagram of initial safety zone is as shown in Fig.2[6].

The initial quarantine refers to the area where the public life is threatened when the accident happens, and is a circle area that the source of leakage is as center. The radius of the circle is the distance of initial isolation. This area only allows a few specialist officers and soldiers of fire protection and rescue team to enter. Protection area (evacuation area) refers to the area that the harmful gas, steam, smoke or dust may affect, and is the square area at downwind direction of source of leakage. The side length of the square is the evacuation distance at downwind direction. If the area is not done protection, it may make one cripple or have serious or irreversible health hazard, so the public should be evacuated, personnel without protection is not allowed to enter or to stay. The initial isolation and protective distance is recommended to protect people and refers to the distance that avoids that people suck poisonous vapors caused by leakage of dangerous chemical to harm health. In 30 minutes after a material leakage, it may have influence and increase the distance with the increase of time.

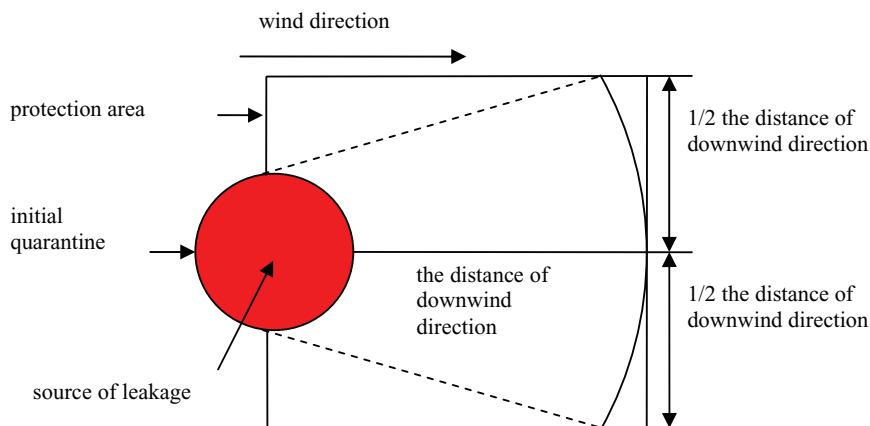


Fig.2. Diagram of initial quarantine and protection area.

4.2. Initial isolation distance and protective distance

The size and the degree of safe distance is decided through the real-time concentration measurement of toxic gas in field and various reference materials. The emergency response plan and guidelines of the air pollution American industrial hygiene association (AIHA) issued provides a detailed classification principle for the real-time concentration monitoring in field. Firstly, it gives three concentration range. ERPG (emergency response plan and guidelines)-1: it refers to the highest concentration in the air. If it is lower than the value, it can believe that almost everyone can expose to it for 1 hour. Except for mild, transitory impact to harm health or obviously unpleasant smell, there is no other influence; ERPG-2: it refers to the highest concentration in the air, If it is lower than the value, it can believe that almost everyone can expose to it for 1 hour. Except for irreversible or other serious effect on health or weakening their ability to take action to protect, there is no other influence; ERPG-3: it refers to the highest concentration in the air, If it is lower than the value, it can believe that almost everyone can expose to it for 1 hour, and it will gradually show the influence of life-threatening health.

At present, AIHA already has released values of ERPG more than 110 kinds of toxic chemical, and it increases seven kinds of chemical each year. As for hazardous chemical materials without value of ERPG, they also put forward the alternative solutions.

The procedure that AIHA determines the safety distance is as follows:

- The values of ERPG are known: the initial isolation distance is determined according to ERPG-3 , and protective distance is determined according to ERPG-2.
- The values of ERPG are unknown: the initial isolation distance is determined according to the value of IDLH or $0.1 \times LC_{50}$, and protective distance is determined according to $0.01 \times LC_{50}$.

Among them, IDLH(Immediately Dangerous to Life and Health) means that people expose to toxic gases for 30 min, and still have the ability to escape. And it is maximum allowable concentration that does not produce adverse symptoms or restorative effects to health. LC_{50} (Lethal Concentration) : it refers to the tested fauna in a certain concentration of chemical exposed a period of time (1-4 h), and have been watched for 14 days, which caused the death of 50% tested fauna [6].

4.3. Regional division of emergency rescue site

The venues that emergency rescue work involves includes the above initial quarantine and protection area. According to the initial safe distance which has determined above, the people at the scene can be evacuated, and can be prohibited to enter to the isolation area. Due to the emergency rescue teams have different functions, contents and areas, the scene of the accident should be divided into further, and it should include areas where emergence personnel, decontamination personnel, and the command personnel are respectively. In this area, work of emergency personnel should be clear which is beneficial to emergency action and effective control for in and out of equipment, and can count the personnel who access to the accident scene.

The three regions are divided at emergency rescue site in typical chemical accidents, as shown in Fig.3. According to the contents at field work and harm level, it is divided in to hot area, warm area and cold area. It belongs to a secure area outside the cold area. The hot area is the dangerous work area, and generally it is also the area with the highest rank of harm.

Besides getting rid of danger, it often need to rescue the wounded people in this area, and it marks with red warning line at the periphery; The warm area is located in outside hot area, and is the area for pollution degradation section. The harm in this area is lower than hot area, and its periphery is marked with yellow warning line; The cold area is also the section to support work, and offers all kinds of support for hot area and warm area, which will be set up headquarters, material storage and personnel rally place, and its periphery is marked with green warning line, and this also is the line to control public crowd, and the boundary that divides the dangerous operation and safety zone(compared characteristics of every area for emergency rescue in dangerous chemical accidents see table 1). Checkpoints are set up in the border of each area, whose purpose is to strictly control the personnel functions and quantity into the area. Check whether the equipment of personnel who enter into every area accord with the personal protection level which every area operations require [2].

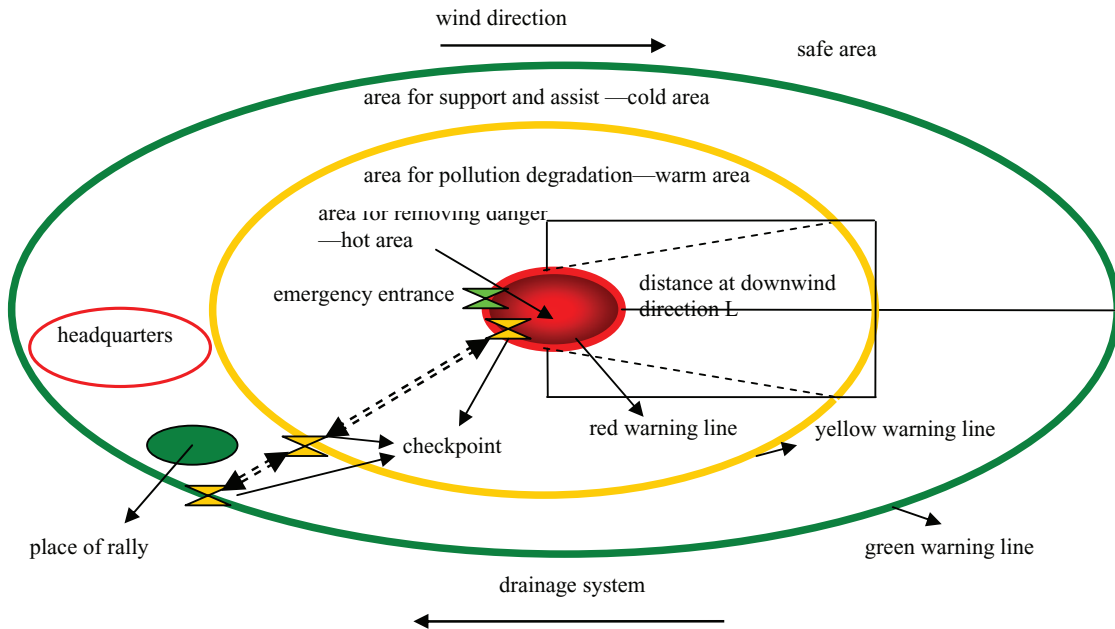


Fig.3 Schematic diagram for regional division of emergency rescue site in dangerous chemical accidents.

5. Personal protection and equipment

Corresponding protection level and standard do not be made in China at present. It usually is divided into three basic protection level abroad, and its protective equipment which forms a complete set according the different levels are as follows:

The protective equipment at first level include overalls, boots, gloves, helmets, airtight goggles, and mask, etc. The protective equipment at this level mainly are used to prevent non-toxic steam, smoke, and dust. In case of large dust, smoke and steam, helmets need to be put on.

The protective equipment at second level include acid and alkali resistant overalls, boots, gloves, hood, and the shield to protect face. The protective equipment at this level mainly are used to prevent spray of Liquid. The hood is connected with the work clothes, and it can be taken down when it need not be desirable. If poisonous chemical produce excitant odor, or produce poisonous vapors, smoke, airtight goggles, mask or antivirus respirator can be used to protect.

The protective equipment at third level include chemical protective clothing of isolation type and chemical protective clothing of fire prevention. They can prevent the liquid, steam, smoke or dust to violate human body. They are effective protective equipment to deal with virulent and corrosively poisonous chemical, carcinogens with long-term effects or suspected carcinogens. Boots is set in chemical protective clothing, and the chemical protective clothing of fire prevention is equipped with antivirus gloves, antivirus respirator is used when chemical accident with fire is implemented[1].

According to provisions of national institute for occupational safety and health, the protection level is divided into 4 levels which are A, B, C, D[1].

Level A: It is a set of completely sealed protective clothing, gloves, boots, and respiration apparatus which needs pressure or a respirator which need pressure to supply air., which can provide the most protection for gas and liquid.

Table 1. Compared characteristics of every area for emergency rescue in dangerous chemical accidents

	Hot area (red area)	Warm area (yellow area)	Cold area(green area)
Another name	Restricted area, excluded area	Decontamination area, Limited access area	Supported area, cleaned area, assisted area
Color of peripheral warning line	red	yellow	green
Area operations	Removing danger,rescuing wounded people	Pollution degradation(decontamination for personnel and equipment and support for hot area)	Support (setting up headquarters, material storage and place of rally)
qualifications requirements of rescue personnel in area	emergency disposal staff with formal training and special equipment must be in the control of security personnel and commander	purification personnel and security personnel who has been trained	Only emergency personnel and the necessary experts
principles of regional division	Detect or evaluate the numerical value is more than 1/2concentration of IDLH or ERPG-3 of toxic chemical substances .	Detect or evaluate numerical value is more than TWA of toxic chemical substances, and is less than 1/2 IDLH or ERPG-3.	Detect or evaluate numerical value is less than TWA of toxic chemical substances.
Protection object	High vapor pressure, gas and liquid that can contact with the skin to absorb; chemical can cause cancer and are highly toxic; Very likely spiling and pouring, contacts, infiltration of liquid with high concentration, and steam exposure: contact with unknown chemical (purity or mixture) : concentration of harmful materials reaches concentration of IDLH ; Lack of oxygen.	Toxic chemical substances are at gaseous state and types of them are known , and can be being absorbed through the skin; Reach concentration of IDLH ; Lack of oxygen.	Toxic gas objects that the skin can not absorb, the type and concentration of poisons are known; It is not the of concentration IDLH ; Don't lack of oxygen.

Note: Use this method with test instrument or according to the computer diffusion model. The TWA is short for time weighted average, and it is the measure to concentration of the chemical gas in a certain time. The average concentration is got by regularly taking number in 8 hours and then averaging. Considering the effectiveness and practicability of the result, we rule that interval time of sampling is not more than 15 minutes, and then all of the results together average namely as a value of TWA in 8 hours.

Level B: It is suitable for use when skin is harmed by steam and it is not serious, and breathing need fully protect. It is different from level A, and it includes a set of not sealed protective gear.

Level C: It is a kind of clothing to prevent from spilling and it is equipped with the respirator of positive pressure or negative pressure and face is completely covered by the respirator (a kind of mask of filtering).

Level D: It only includes coverall or other work clothes, boots and gloves.

Combined the regional characteristics at emergency rescue site in dangerous chemical accidents with hierarchies characteristics of foreign protection, we can do the following requirements for the personal protection of emergency rescuers at every area in dangerous chemical accidents (see table 2).

Because there are many harmful factors in at the scene of chemical accidents, we should fully consider all kinds of hazard factors and protect different parts of the body. Personal protective equipment of rescue workers should be chosen based on the rescue mission and the position of dangerous region, and it should follow the principle that can be reliable protection and take effective rescue. Except for personal protective equipment for fire protection and some special equipment, other protective equipment of respiratory tract and skin generally don't have the function of fire prevention, so we should be careful in the occasion of fire in chemical accidents if we use them. When protective equipment of respiratory tract are used, we need pay attention to the effective protective time of equipment itself. Filtering mask can be estimated according to data that equipment performance has listed; Isolated mask can be used according to prescribed time, when the automatic warners alarms , we should leave danger area quickly. The protective ability of simple and handy protective equipment of respiratory tract is low, and it is only comfortable to emergency situation and can not use for a long time. When personal protective equipment is used, the adverse effect on physiology the equipment itself brings will pay much attention to. Such as heavy or light protection clothing with isolation have great impact on personnel physiology, because the human body is completely cut off to outside world, the normal cooling process is suffocated, when it is used in high

temperature, people may have the risk of sunstroke if it is worn for a long time, so people should comply with time limit of equipment use or adopt cooling measures.^[8]

Table 2. Requirements for the personal protection of emergency rescuers at every area in dangerous chemical accidents

	Hot area (red area)	Warm area (yellow area)	Cold area(green area)
Classification of national institute for occupational safety and health	Level A	Level B	Level C
Requirements of personal protection	Provide maximum protection for gas and liquid	The situation that steam harms the skin is not serious, and breathing need fully protect.	Harm of gases is small, breathing need proper protection.
Details of requirements			
Protective clothing	A set of completely sealed protective clothing is needed	A set of not sealed protective clothing is needed to prevent chemical liquid to penetrate	need
Gloves, shoes and boots	Completely hermetical gloves and boots are needed to resist chemical, and they are connected to chemical protective clothing	Gloves, shoes and boots with acid and alkali resistant are needed	need
Protection of eyes and face	Airtight goggles, and safety helmet are needed	The airtight goggles with acid and alkali resistant is needed, and the hood is connected with the work clothes	need (In case of large dust, smoke and steam, helmets need to be put on.)
Respiratory protection	The air respirator of positive pressure with comprehensive cover is needed	The air respirator of positive pressure with comprehensive cover is needed	The mask or respirator can prevent from non-toxic steam, smoke and dust.

6. Summary

- Perfect the rescue plan. Based on the requirements of fast, accurate and effective emergency rescue in dangerous chemical accident, it need fully and elaborate plan to prepare. Moreover, we need be specific and refined to information transmission content of dangerous chemical in the plan; Combined with local wind direction, water drainage and geographical environment, a diagram of regional division is designed as accurately as possible; According to the demand, the configuration of personal protective equipment at each area should be clear.
- Strengthen the protection training and exercises. Emergency rescue workers not only need do the accurate judgment to the accident, but also they need fully understand and master the performance of protective equipment. So the theory training of protective equipment, the targeted protection training and drill are required.
- Improve the level of daily management and resources sharing. Standard each link include selection, purchase, the personnel screening, personnel allocation, use and training, maintenance, decontamination, and discarding, etc. Use information management technology to strengthen resources sharing of rescue protective equipment between departments and units.
- Pay attention to the dress reaction of rescue workers, and timely change protection level. The protective equipment not only brings the inconvenience of action, but also it can produce "response" of protection, which has influence of different degrees on the normal physiology function of human body. Especially, when people wear breathing apparatus, and dress chemical protective clothing of isolation, normal breathing of human body and the heat dissipation of body are restricted, and respiratory resistance is big and the whole body is hot, which can appear headache, nausea etc. The protection level is higher in the early rescue in hot area; When toxicity is not great or the concentration has been reduced, it can drop for low level of protection.
- The product research of personal protective equipment should focus on new technology research and development in order to improve the protect coefficient of gas mask ; Develop the protective clothing with light weight, small size, and low heat stress.

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